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14. ABSTRACT
Thin film paper supercapacitor successfully designed and fabricated. Test results validate the fabrication processes developed.We classify this project as a success defined by the surpassing of our initial design goals. This success paves the way for future work to be done.

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Paper supercapacitors

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Report Title: Thin film Paper Supercapacitors
Report Type: Technical Report

Thin Film Paper Supercapacitors

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Outline

- Introduction
- Motivation
- Methodology
- Experimental Results
- Conclusions

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Introduction

What are supercapacitors?

- **Supercapacitors are outstanding energy storage devices.**
- **Comprised of two electrodes separated by a dielectric.**
- **Stores energy in the form of an electric charge.**

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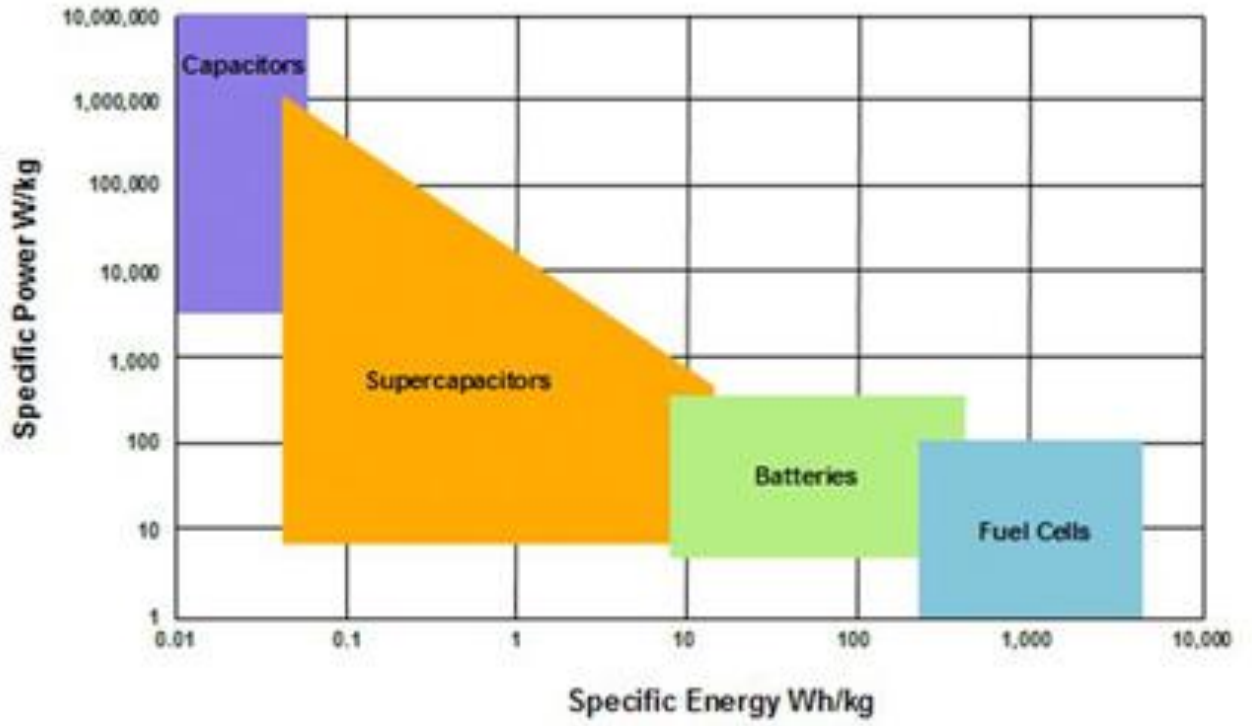
Supercapacitor advantages



More advantages

- **Long Cycle Life**
- **High Efficiency**
- **High Reliability**
- **Wide Working Temperature**

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Problem Statement

- **Achieve thin lightweight devices that can be stacked closely together.**
- **Not much work has been done in furthering the development of ideal supercapacitors.**
- **Paper Supercapacitors naturally can’t attain capacitance levels of regular EDLC’s.**

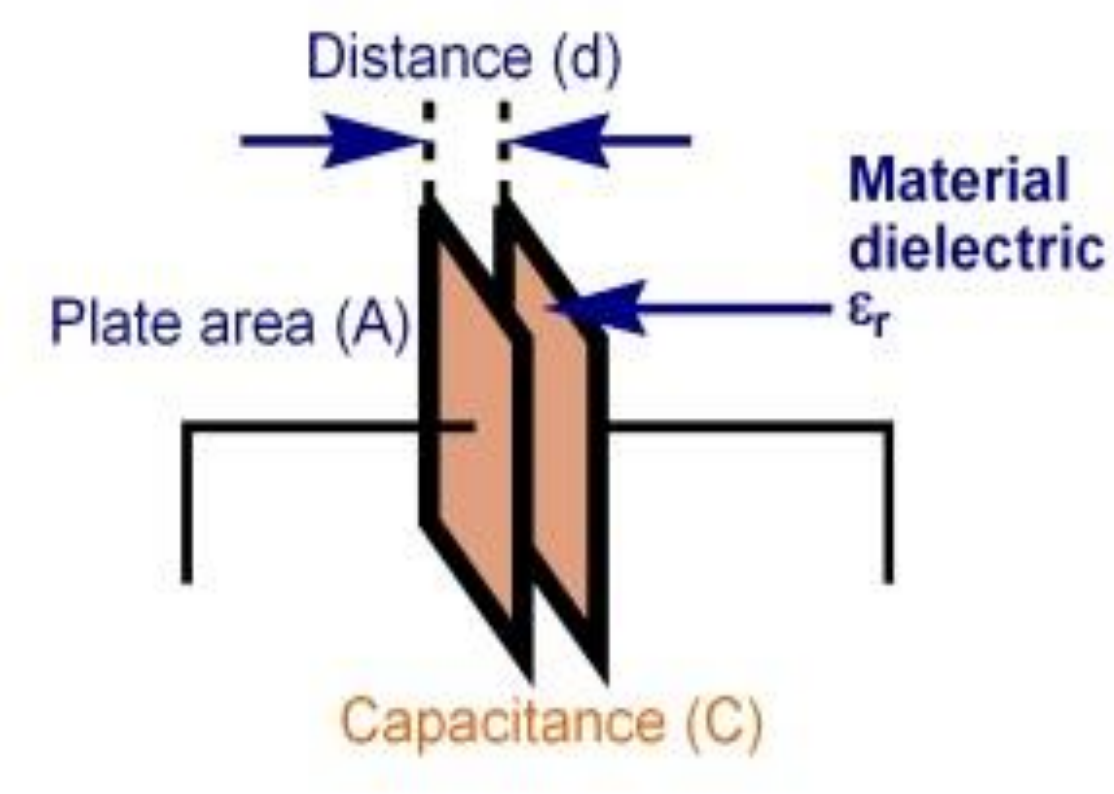
Motivation

- **Unplug everything**
- **Portable applications**
- **Thin, light-weight ➔ More functionality**
- **Global clean energy focus**
- **Supercapacitors are now being used for applications usually reserved for batteries.**

http://www.theroguenews.com/2011/05/4701/http://www.bjjtgl.gov.cn/publish/portal1/tab176/

Theory/Key Equations

- $C \alpha A$
- $C \alpha 1/d$
- $C = \frac{\varepsilon_0 \varepsilon_R A}{d}$



http://www.calctool.org/CALC/eng/electronics/parallel_plate

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Design Goals

- **Use of paper based electrode material.**
- **Use of paper or polymer electrolyte material.**
- **Planar capacitance of 25 μF/cm^2**
- **Device weight less than 1 gram**
- **Device thickness less than 1mm**

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Device Design

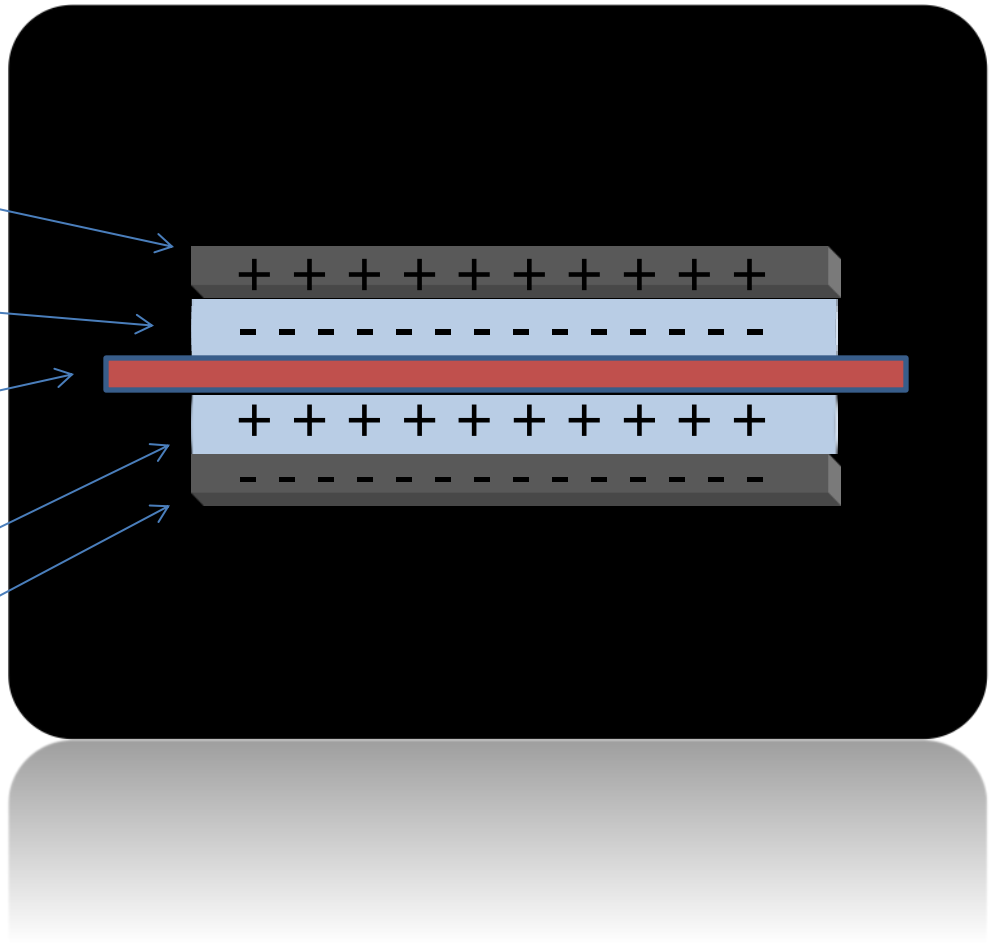
Electrode (Carbon Paper)

Electrolyte (H_3PO_4)

Separator (PVA)

Electrolyte (H_3PO_4)

Electrode (Carbon Paper)



Materials

- **Electrode Layers:**
  - ***Spectra carbon fiber paper, Toray carbon fiber paper, silver nanoink, Multi-wall carbon nanotubes***
- **Separator:**
  - ***Polyvinyl Alcohol (PVA)***
- **Electrolyte:**
  - ***Phosphoric Acid (H_3PO_4)***

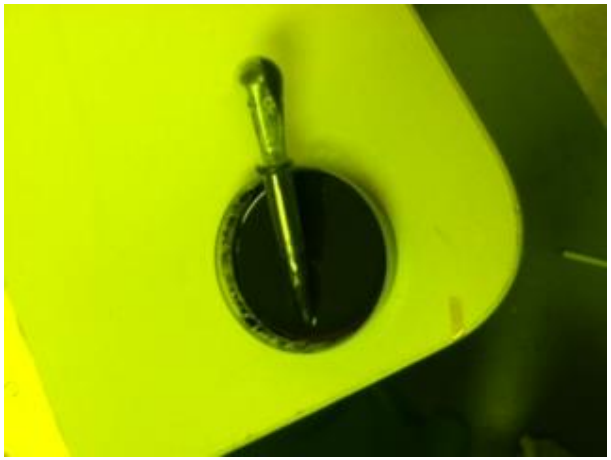
Electrodes

- Carbon Fibers
  - Toray Teflon 30
  - Toray Teflon 60
  - Spectra carbon
  - Multi-wall Carbon Nanotubes
- Silver Nano-particulate ink

✓ Electrically conductive

✓ Very large surface area

✓ Highly porous



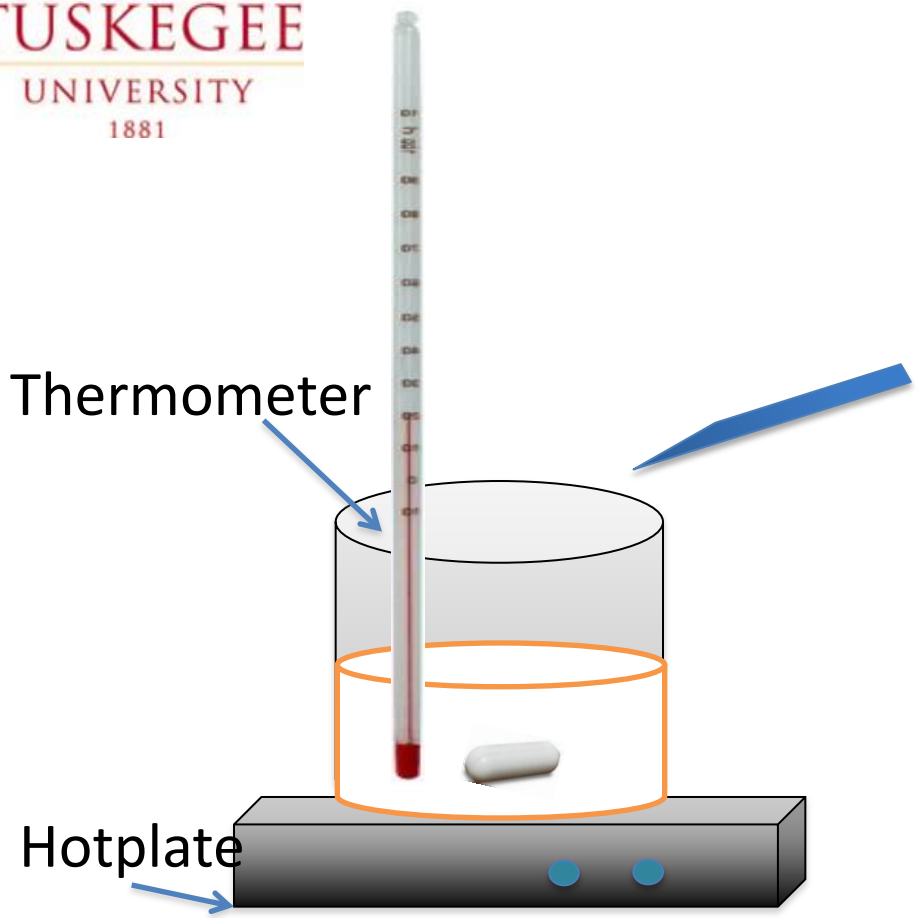
Electrolyte/Separator

- **Phosphoric acid (H_3PO_4)**
  - **Acts as an ionic liquid**
- **Polyvinyl Alcohol (PVA)**
  - **Allows movement of ions**
  - **Functions as a separator between the two electrodes.**

Fabrication

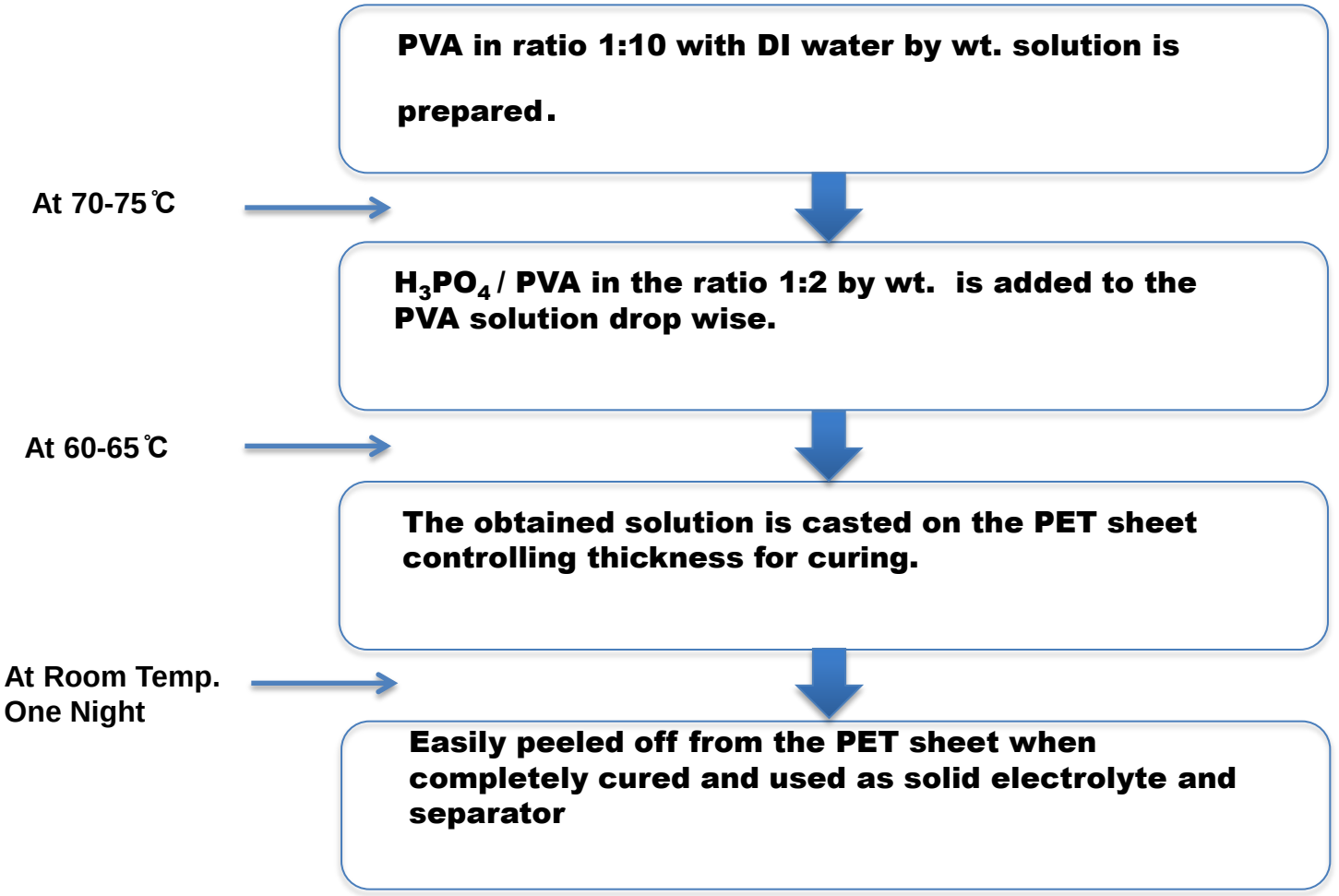
- **The first step in creating our supercapacitor was to make the electrolyte which consisted of PVA and H_3PO_4.**

Electrolyte Fabrication



1. Place water in beaker
2. Heat to 70 ^{o}C
3. Slowly add PVA
4. Slowly add H_3PO_4 dropwise

Solid Electrolyte Fabrication



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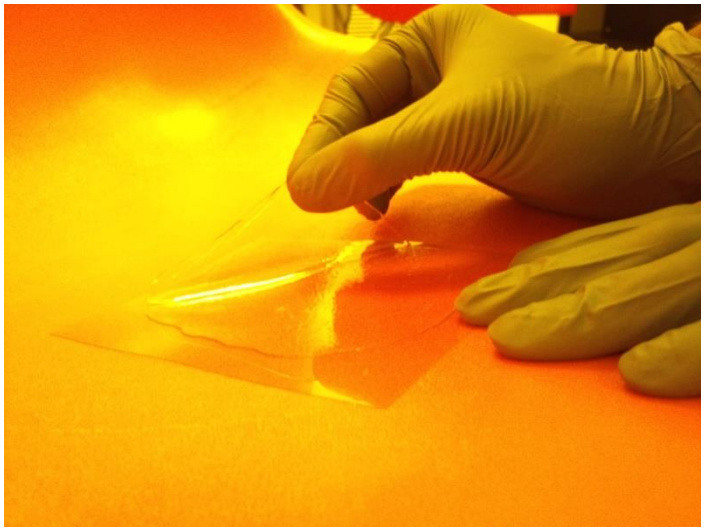
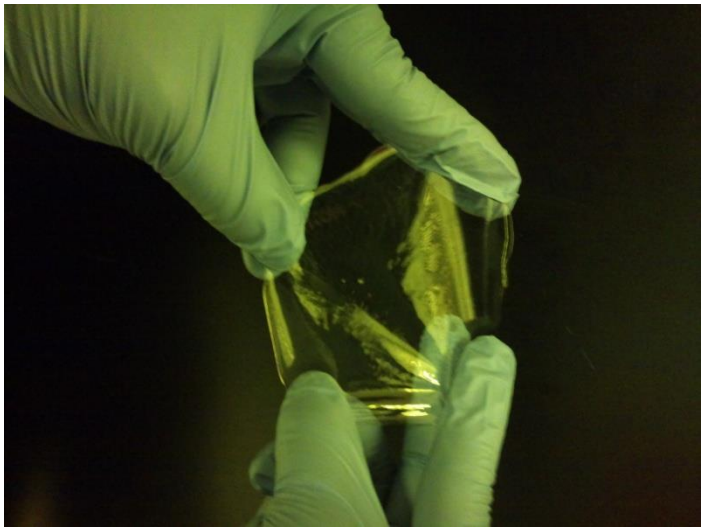
Solid Electrolyte Fabrication





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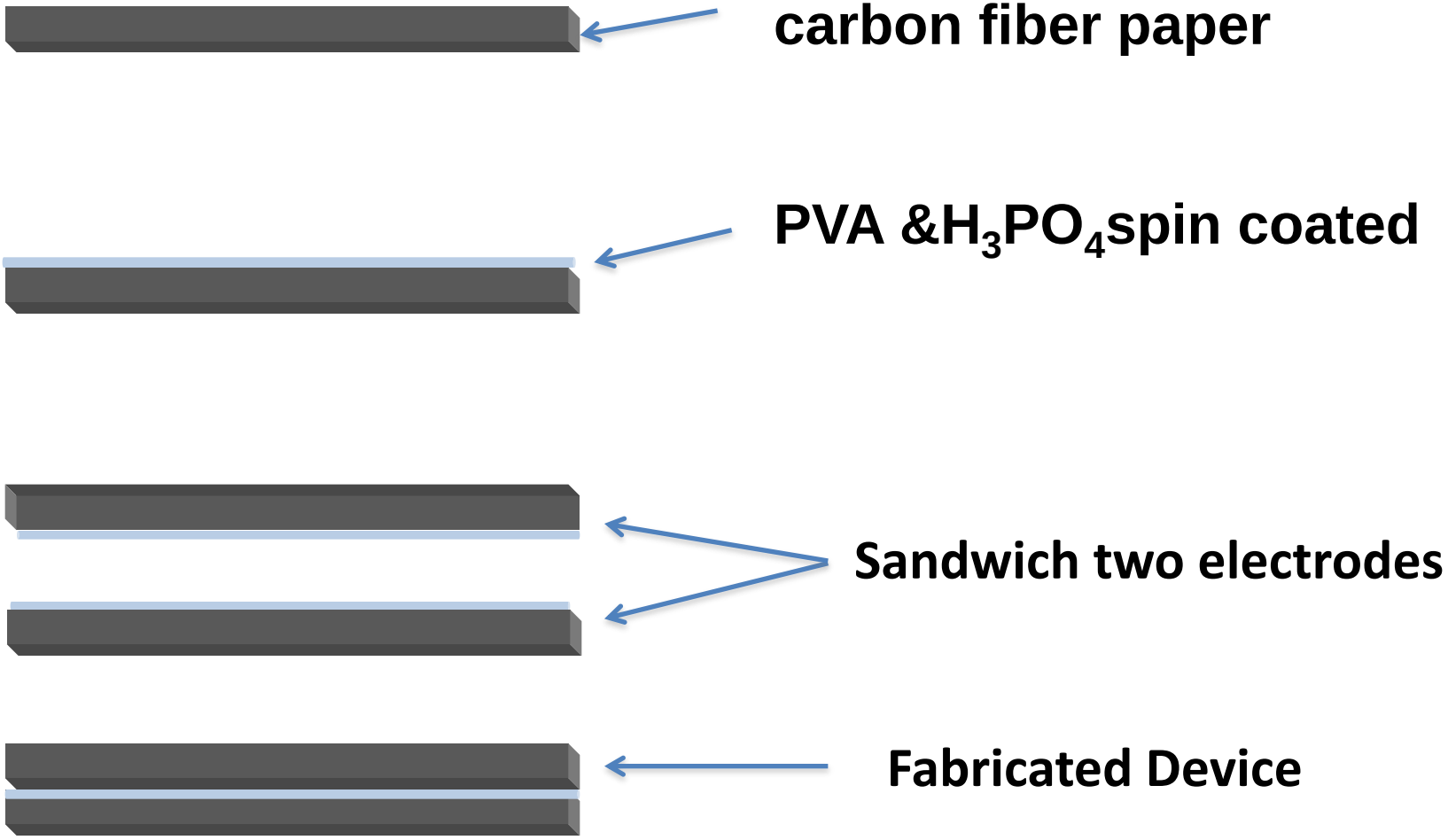
Device Fabrication



Fabrication Methods

- **Spin coating.**
- **Dispensing.**
- **Meyer rod method.**

Spin Coating

- A popular method of coating.
- Used to apply the silver nano-particulate ink and carbon nanotubes as electrode layers.
- Silver nano-particulate ink - Spin coated at 200 rpm for 30 seconds.
- Carbon nanotubes - Spin coated at 100rpm for 30 seconds.

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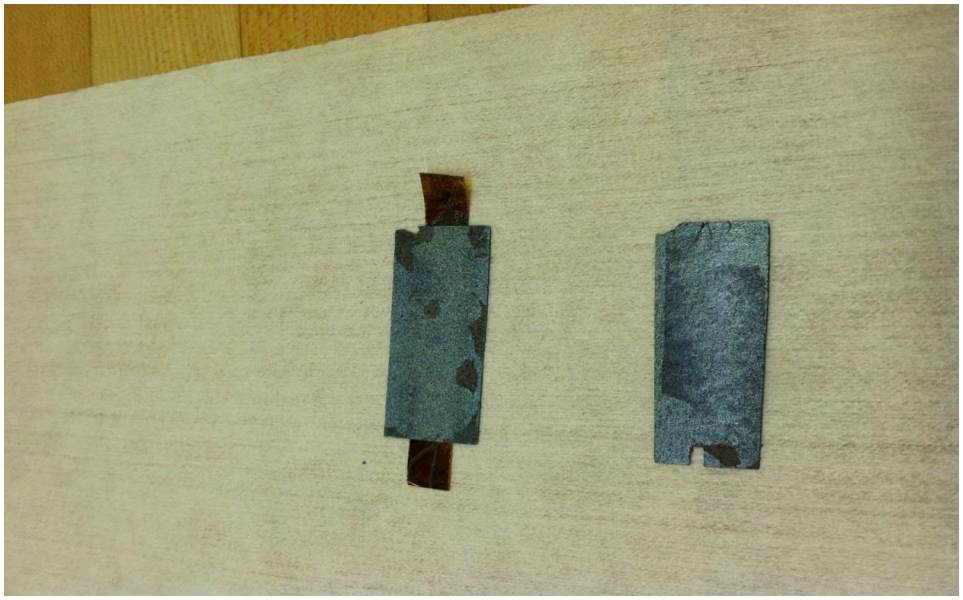
Spin Coating

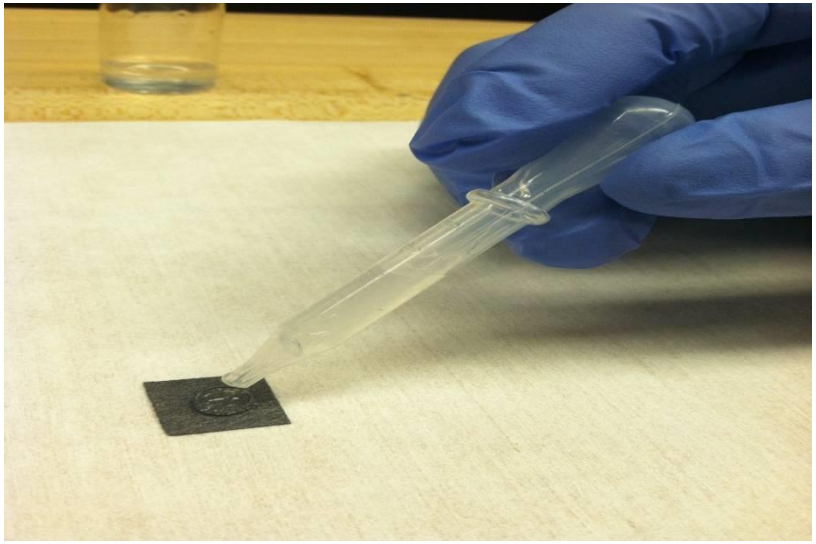
Carbon paper with a spin coated layer of nano-particulate ink on its surface.



Dispensing Method

- The PVA/H_3PO_4 solution is applied in drops by the use of a pipette.
- The solution is allowed to dry for 10 minutes.

- Electrodes are then placed together.



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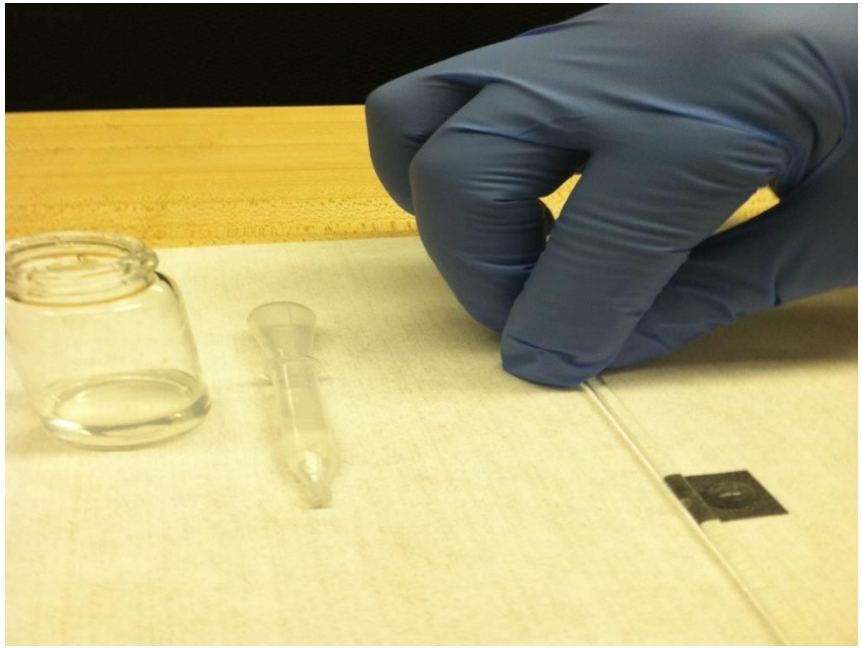
Meyer Rod Method

- **A cylindrical rod is used to spread the excess coating solution and control the coating distribution across a surface.**

- **Used to make coatings of electrolyte on electrode surfaces.**



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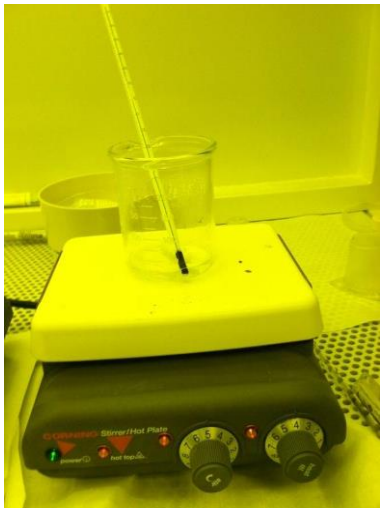
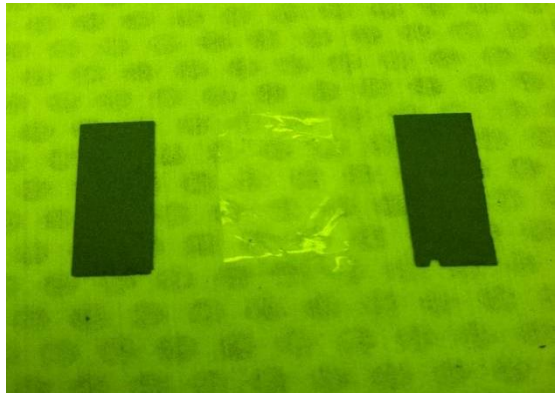
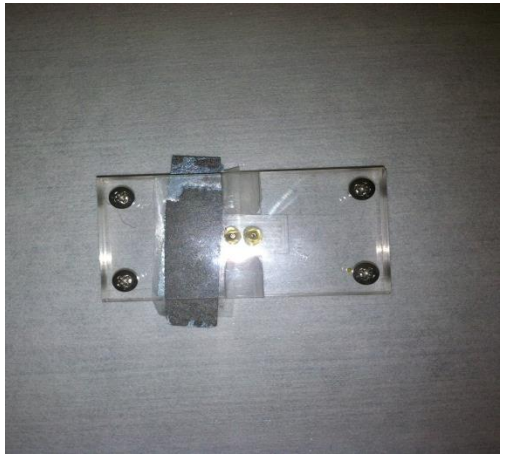
Device Assembly







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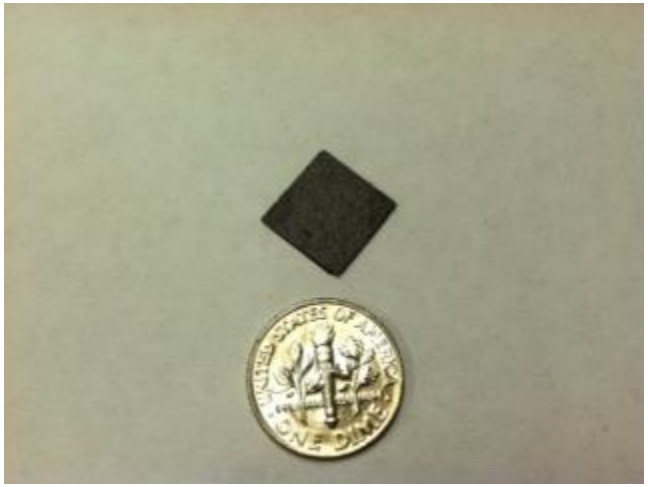
Stand-alone Device



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Experimental Results

Toray Carbon 120 µm Thick sandwiched w/ Solid Electrolyte 50 µm thick (3cm x 1cm)	Planar capacitance µF/Sq. cm
Ag nano ink & Carbon nanotubes	140
Ag nano ink	64.95
Without Ag nano ink	0.3

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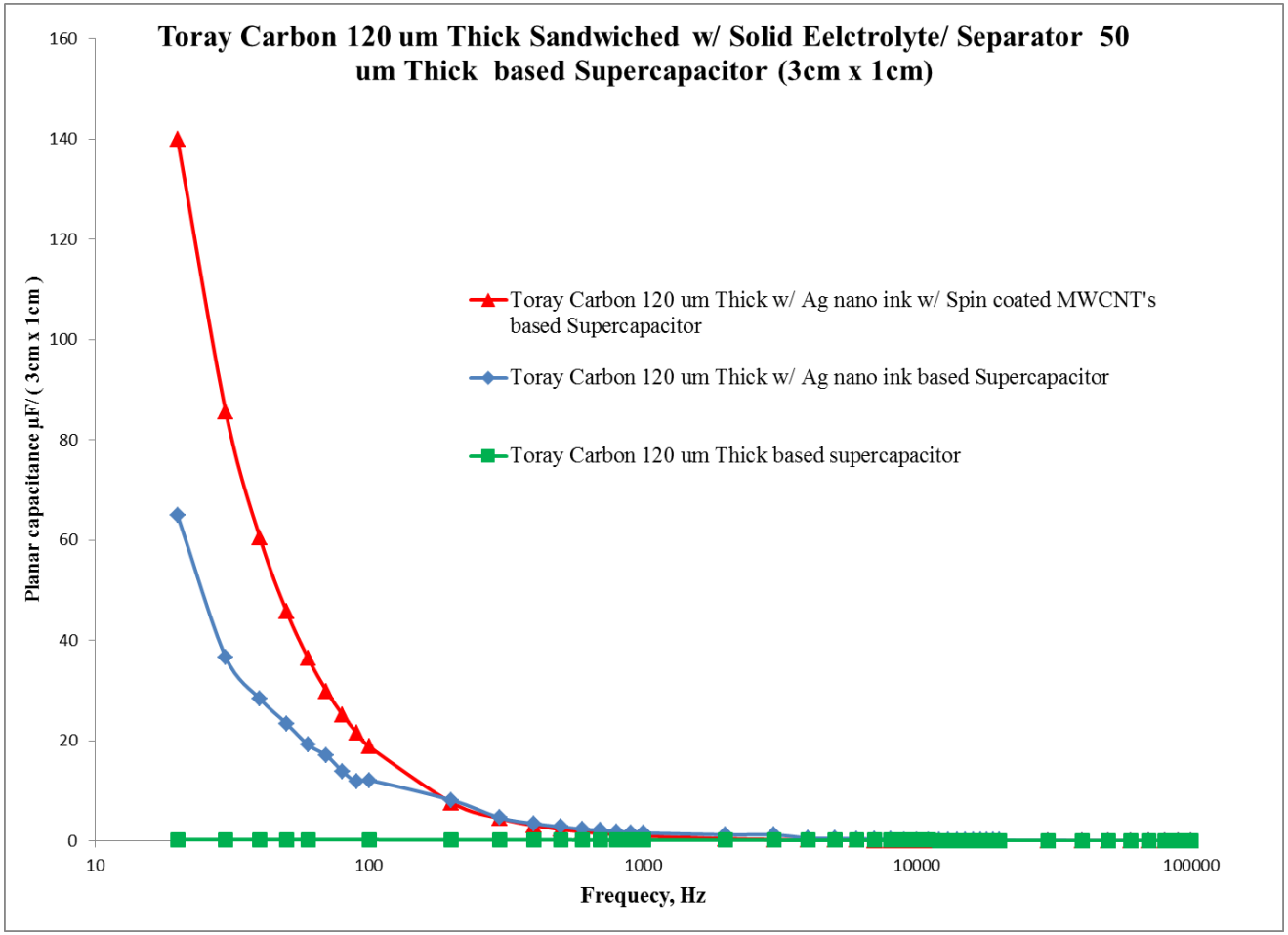
Experimental Results



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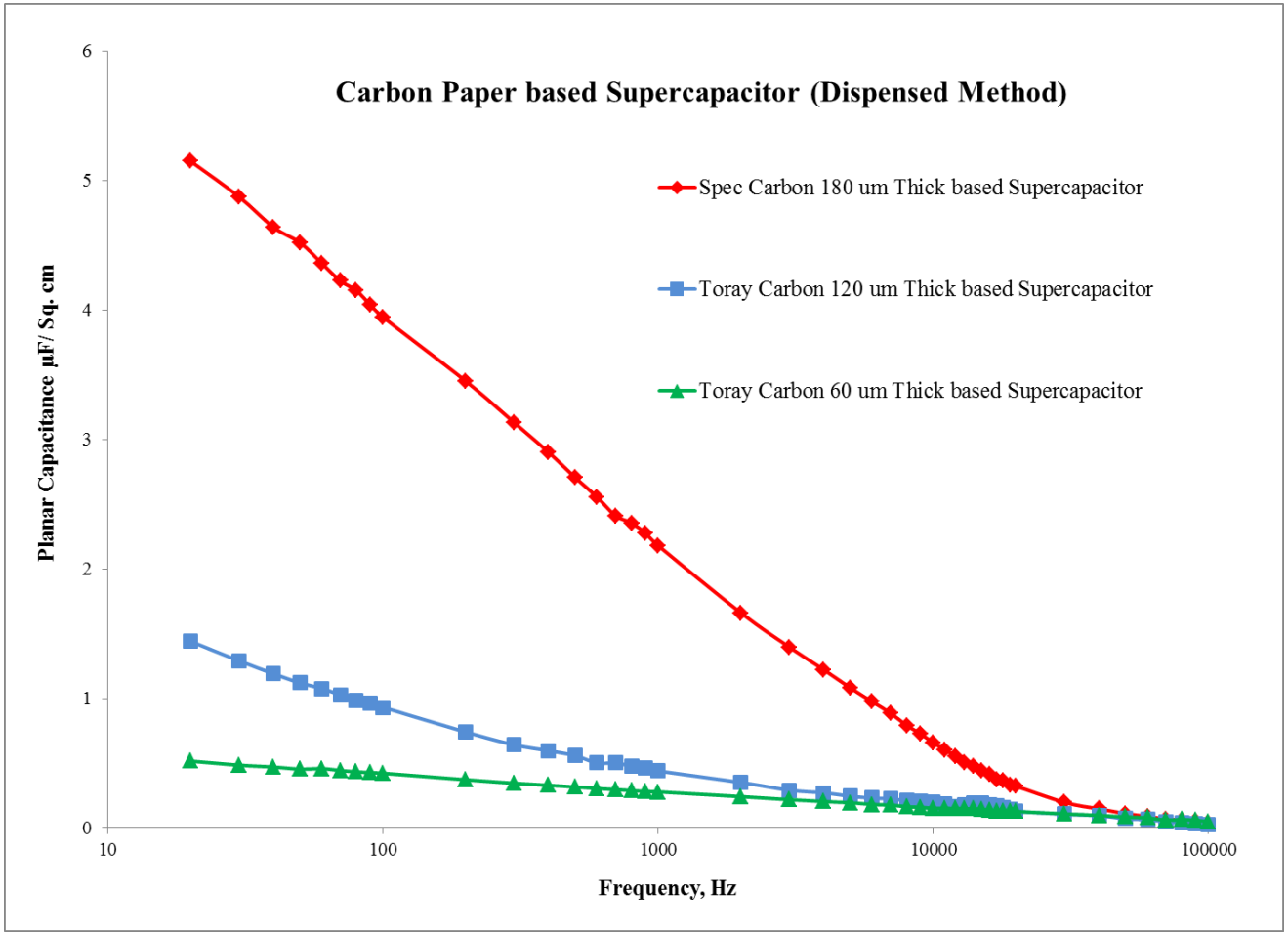
Experimental Results



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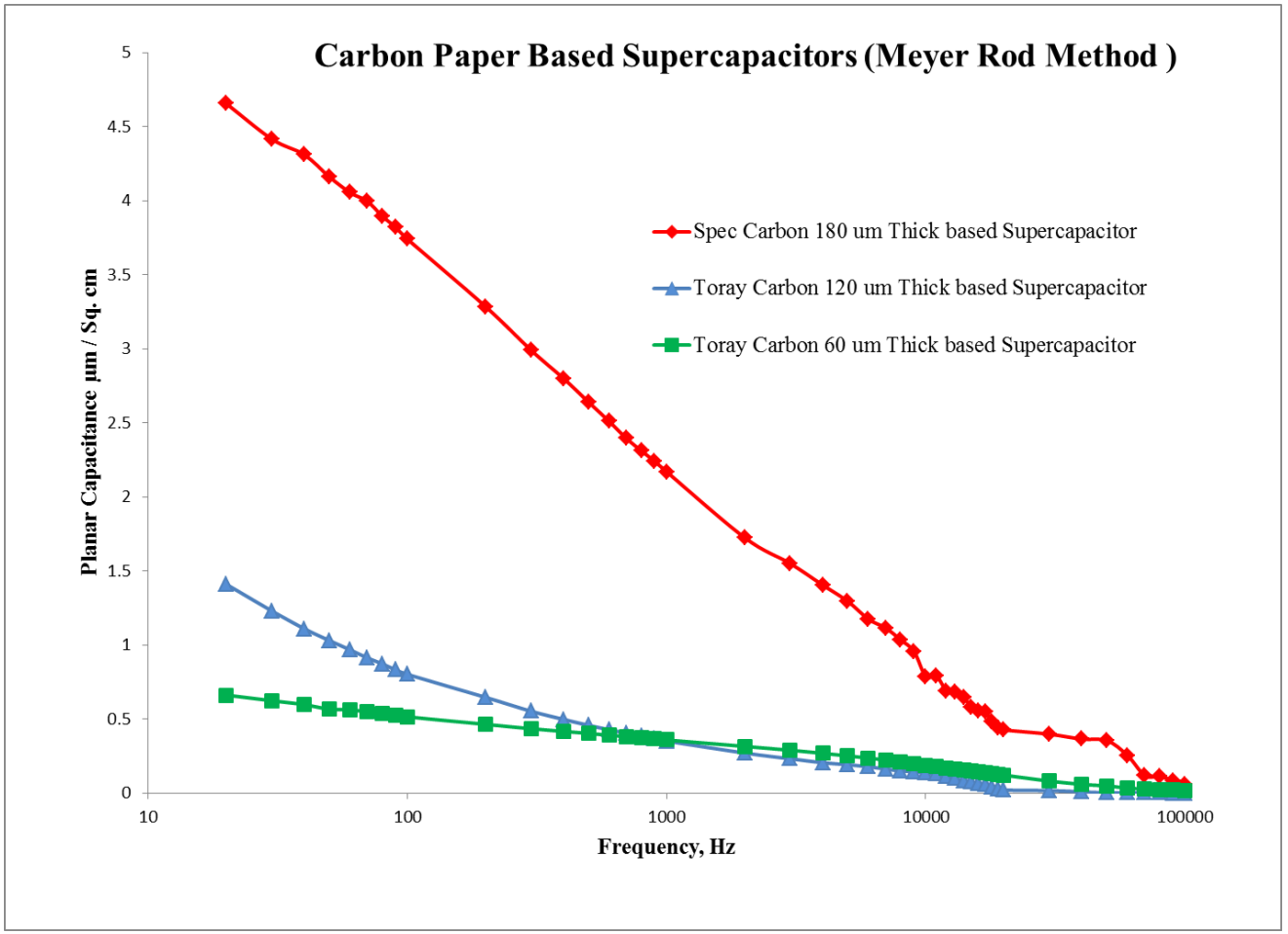
Experimental Results



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Conclusions

- ✓ **Thin film paper supercapacitor successfully designed and fabricated.**
- ✓ **Test results validate the fabrication processes developed.**
- ✓ **We classify this project as a success defined by the surpassing of our initial design goals.**
- ✓ **This success paves the way for future work to be done.**

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